ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

ECOSTRESS

Simon J. Hook and the ECOSTRESS Team
Jet Propulsion Laboratory,
California Institute of Technology, Pasadena, CA

With support, encouragement and participation from many!

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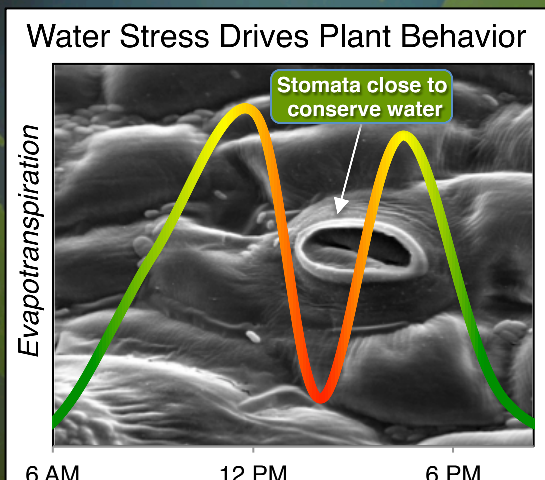
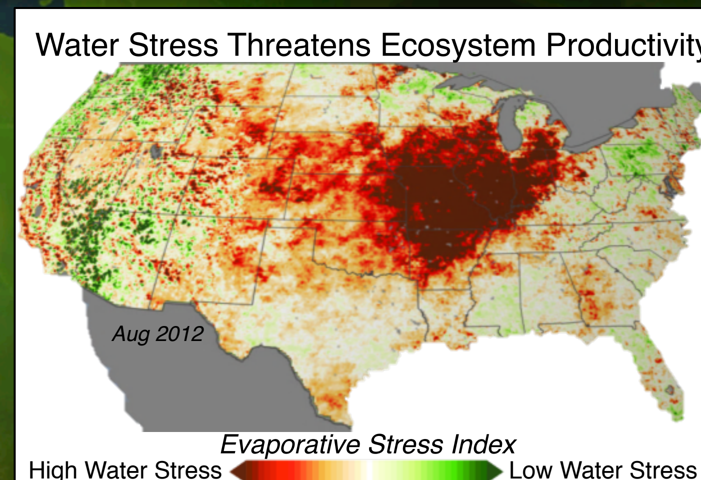
Dr. Simon J. Hook, JPL, Principal Investigator

Science Objectives

- Identify **critical thresholds of water use and water stress** in key climate-sensitive biomes
- Detect the timing, location, and predictive factors leading to plant **water uptake decline** and/or cessation over the **diurnal cycle**
- Measure **agricultural water consumptive use** over the contiguous United States (CONUS) at spatiotemporal scales applicable to improve drought estimation accuracy



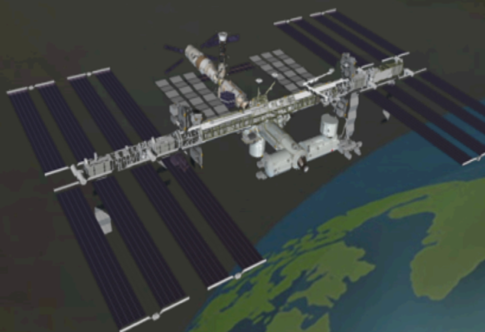
When stomata close, CO_2 uptake and evapotranspiration are halted and plants risk starvation, overheating and death.

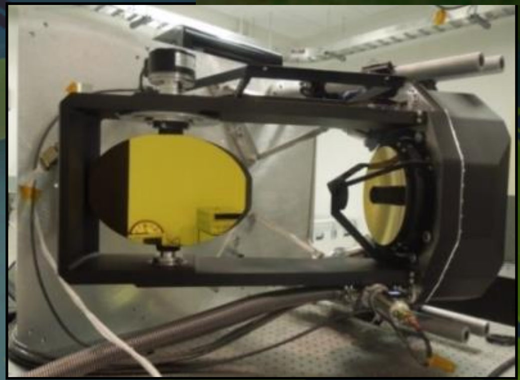


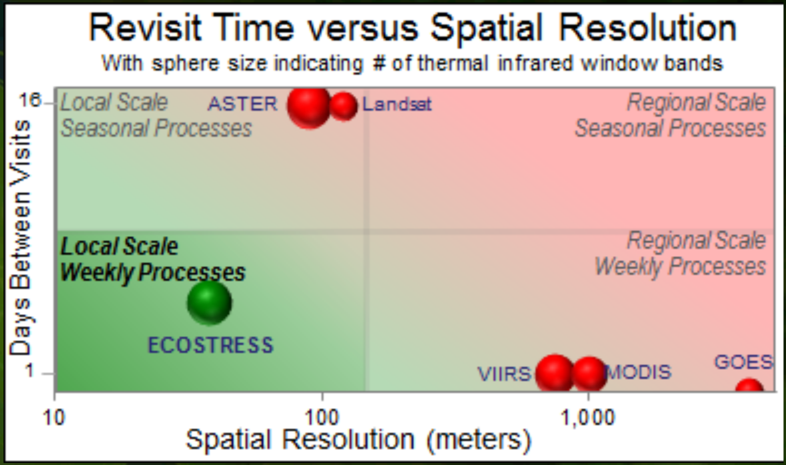
Water stress is quantified by the Evaporative Stress Index, which relies on evapotranspiration measurements.

*ECOSTRESS will provide critical insight into **plant-water dynamics** and how **ecosystems change with climate** via **high spatiotemporal** resolution thermal infrared radiometer measurements of evapotranspiration from the International Space Station (ISS).*

ECOSTRESS

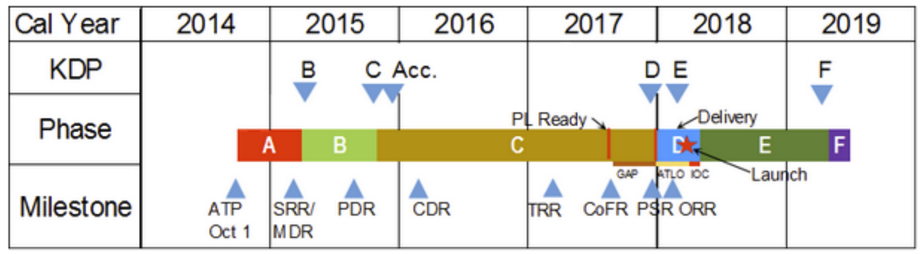






Mission

- Class D $30M cost cap
- 31-months from project start to delivery
- JPL implementation and management
- 69-month project duration (Phase A-F)
- On ISS-JEMS Module
- 12-month Science Operations (Phase E)

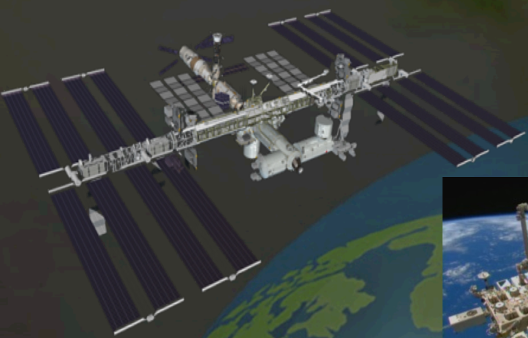


The inclined, precessing ISS orbit enables ECOSTRESS to sample the diurnal cycle in critical regions across the globe at spatiotemporal scales missed by current instruments in Sun-synchronous polar and high-altitude geostationary orbits.

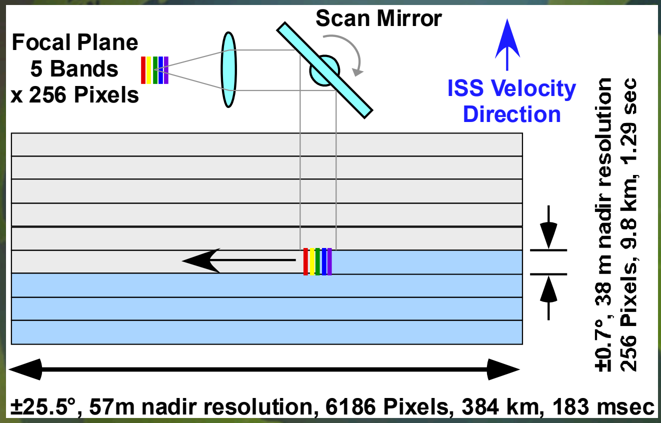
Instrument

- Leverages functionally-tested PHyTIR space-ready hardware developed under the NASA Instrument Incubator Program:
  - Spectral resolution: 5 bands in the thermal infrared window (8-12.5 μm) part of the electromagnetic spectrum
  - Noise equivalent delta temperature: ≤ 0.3 K
  - Spatial resolution: 38 m x 69 m
  - Swath width: 400 km @ 400 km altitude (51°)
- *Well understood measurement and algorithms based on prior missions, such as ASTER, MODIS, and Landsat*

ECOSTRESS



Push-whisk System



Science Data Products	
L0	Raw data
L1	Radiometrically corrected Brightness Temperature
L2	Surface Temperature and Emissivity
L3	Evapotranspiration
L4	Water Use Efficiency, Evaporative Stress Index

Science Team

Principal Investigator

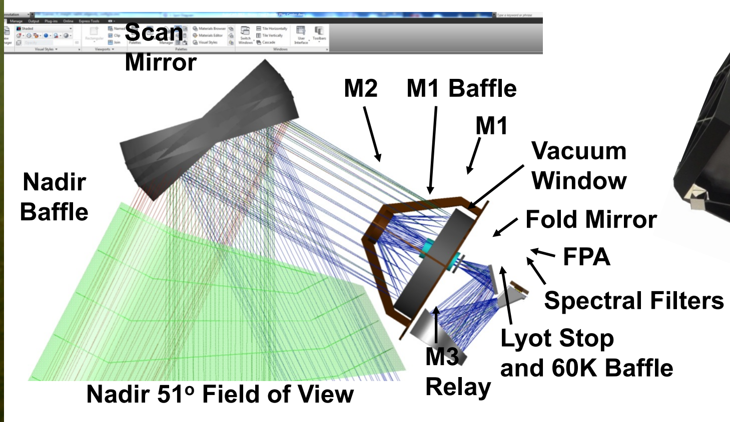
Simon Hook, JPL

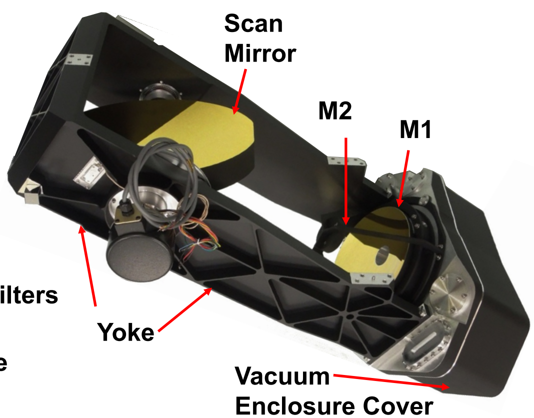
Co-Investigators

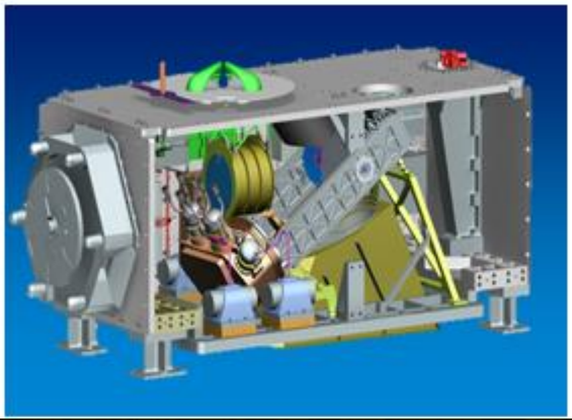
Rick Allen, Univ. of Idaho
Martha Anderson, USDA
Joshua Fisher, JPL
Andrew French, USDA
Glynn Hulley, JPL
Eric Wood, Princeton Univ.

Collaborators

Christopher Hain, Univ. Maryland

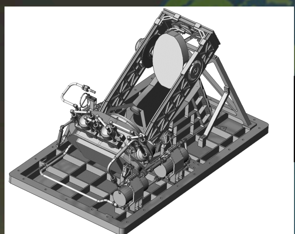




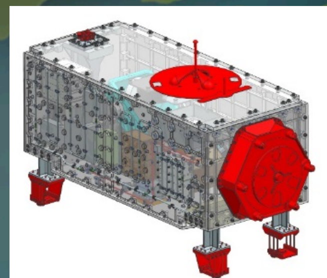


Mission Concept

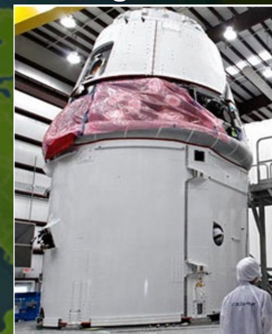
Radiometer Instrument



ECOSTRESS Payload

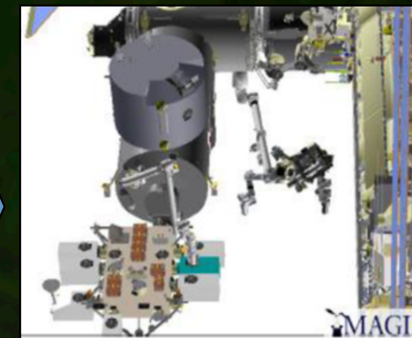


Dragon-Trunk

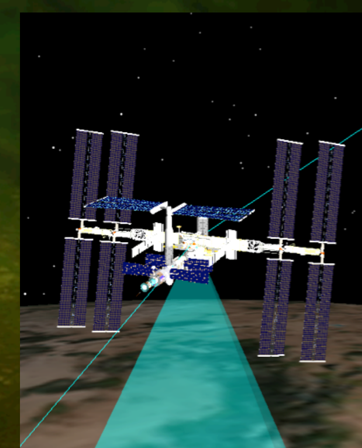


Falcon-9 LV

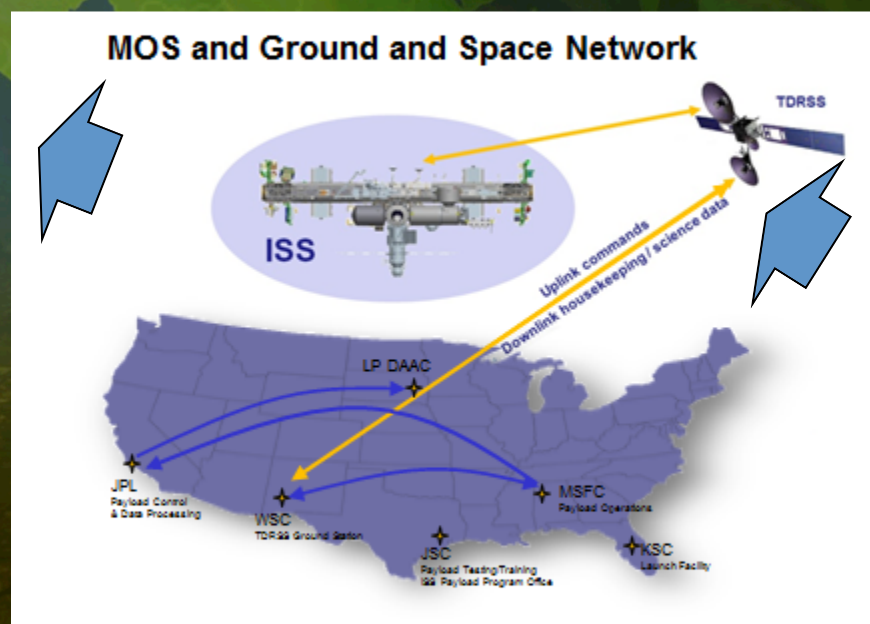
Installation on JEM-EF



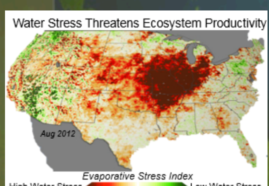
Data Collection

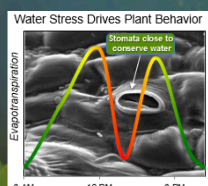


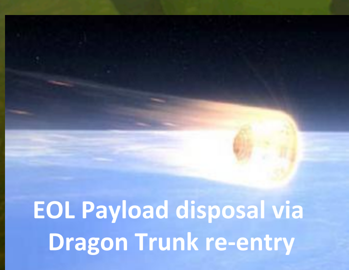
MOS and Ground and Space Network



Science Data Processing and Archive







Current Events

- 4/26/17 ETRR
- ~~02/08/17 Feb MMR~~
- ~~01/30-31/17 ECOSTRESS Ops TIM at Marshall~~
- ~~01/12/17 Jan MMR~~
- ~~12/14/16 Dec MMR~~
- ~~11/29-30/16 JAXA TIM at Caltech~~
- ~~11/09/16 Nov MMR~~
- ~~09/27/16 RT validation test~~
- ~~09/14/16 Sept MMR~~
- ~~08/10/16 Aug MMR~~
- ~~07/26-28 POIWG~~
- ~~07/13/16 July MMR~~
- ~~06/08/16 June MMR~~
- ~~05/11/16 May MMR~~
- ~~04/14/16 Post-CDR Briefing to DPMC~~
- ~~04/12/16 April MMR~~
- ~~03/29/16 Post-CDR DMC~~
- ~~03/08-09 Project CDR~~
- ~~02/10/16 February MMR~~
- ~~02/11/16 SpaceX Interface Telecom~~
- ~~02/10/16 ISS Interface CDR~~
- ~~02/09/16 Phase II Safety Review~~
- ~~01/27/16 POIWG~~
- ~~01/26/16 Payload I&T and ATLO Peer Review~~
- ~~01/25/16 V&V Peer Review~~
- ~~01/20/16 Firmware Peer Review~~
- ~~01/13/16 January MMR~~
- ~~01/12/16 Fracture Control Board Review 4~~
- ~~01/07/16 Radiometer Mechanical Peer Review~~
- ~~01/04/16 Phase II Safety Data Package due~~
- ~~12/17/15 Thermal Peer Review~~
- ~~12/16/15 Electronics Peer Review~~
- ~~12/15/15 Telecom Peer Review~~
- ~~12/14/15 Optics, Detector & Calibration Peer Review~~
- ~~12/10/15 Accommodation Confirmation Briefing to DPMC~~
- ~~12/07/15 Fracture Control Board Review 3~~
- ~~12/07/15 FSW Peer Review~~
- ~~12/04/15 MOS, GDS, and SDS Peer Review~~
- ~~12/02/15 Radiometer I&T Peer Review~~
- ~~12/02/15 Science Peer Review~~
- ~~11/18/15 Payload Enclosure Peer Review~~
- ~~11/16/15 Fracture Control Board review 2~~
- ~~11/11/15 November MMR~~
- ~~11/05/15 Science Team Meeting #2~~
- ~~10/29/15 Scan Mechanism Peer Review~~
- ~~10/23/15 KDP-C~~
- ~~10/20/15 Fracture Control Board review 1~~
- ~~10/14/15 October MMR~~
- ~~10/05/15 DMC~~
- ~~09/16/15 September MMR~~
- ~~08/12/15 August MMR~~
- ~~07/28/15 PDR~~
- ~~07/23/15 JAXA Face to Face meeting~~
- ~~07/14/15 Phase I Safety Review~~
- ~~07/01/15 Science Peer Review~~
- ~~06/30/15 Telecom SS Peer Review~~
- ~~06/24/15 JAXA Technical Exchange Meeting~~
- ~~06/23/15 ISS Interface PDR~~
- ~~06/19/15 Thermal Peer Review~~
- ~~06/18/15 Optics and Detector Peer Review~~
- ~~06/17/15 June MMR~~
- ~~06/16/15 Scan mechanism Peer Review~~
- ~~06/15/15 Radiometer structure Peer review~~
- ~~06/11/15 Enclosure tabletop review~~
- ~~06/10/15 Electronics Peer Review~~
- ~~06/10/15 MOS/GDS and SDS Peer Review~~
- ~~06/05/15 FSW Peer Review~~
- ~~05/27/15 II&T and ATLO Peer Review~~
- ~~05/26/15 Firmware Peer Review~~
- ~~05/21/15 Motor Control Peer Review~~
- ~~05/21/15 WAP Downselect~~
- ~~05/20/15 Wi-Fi Tabletop Review~~
- ~~05/13/15 May MMR~~
- ~~05/06/15 Heat Exchanger Design Review~~
- ~~04/30/15 Cold Panel Peer Review~~
- ~~04/16/15 Cryocooler thermal analysis Tabletop~~
- ~~04/16/15 Signal Chain/Flex Peer Review~~
- ~~04/15/15 KDP-B~~
- ~~04/08/15 April MMR~~
- ~~03/25/15 Wi-Fi WG at JSC~~
- ~~03/24/15 Safety TIM/phase 0 at JSC~~
- ~~03/17/15 JAXA Briefing~~
- ~~03/11/15 March MMR~~
- ~~03/05/15 Inheritance Review~~
- ~~02/10/15 SRR/MDR~~
- ~~01/14/15 January MMR~~
- ~~01/12/15 Baseline Walkthrough~~
- ~~12/14/14 ECOSTRESS Science Team Meeting~~
- ~~12/10/14 December MMR~~
- ~~11/19/14 November MMR~~
- ~~11/06/14 ISS Kickoff Meeting~~
- ~~11/04/14 ESSP/SMD Meeting~~
- ~~10/01/14 Authority To Proceed (ATP)~~

Project Status Summary

Technical			Schedule			Programmatic			Resources		
FEB	MAR	APR	FEB	MAR	APR	FEB	MAR	APR	JAN	FEB	MAR
Y	Y	Y	Y	Y	Y	G	G	G	Y	Y	G

Detailed Description: **(for items identified as yellow or red)**

Technical: Firmware on DPU-I/O has limited data band-width, data compression not implemented/working and data sent to GDS was not readable during thermal ambient test.

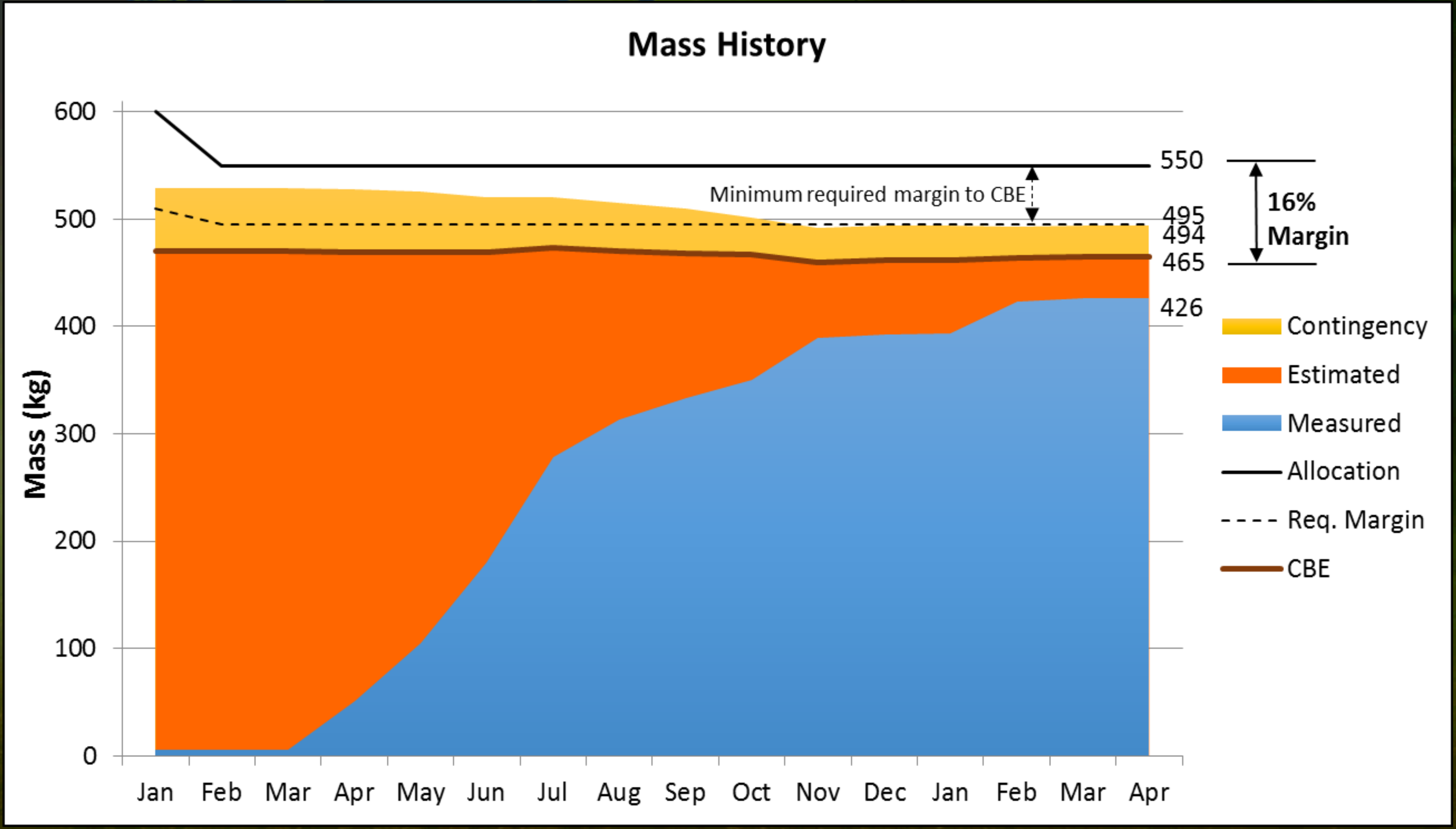
SpX changed the interface design to the Dragon Trunk from pFSE 1.0 to 2.0 design. Still evaluating the changes needed to random vibration testing MGSE.

Schedule: Cryocooler Multiplexer (CCM) would not switch from side-A to side-B of redundant cryocooler electronics. Request to change the delivery schedule submitted to ESSPO.

G	No Current Problem All commitments can be met
Y	Significant problem Identified solution Commitment is in jeopardy
R	Major Problem No identified solution Commitments cannot be met

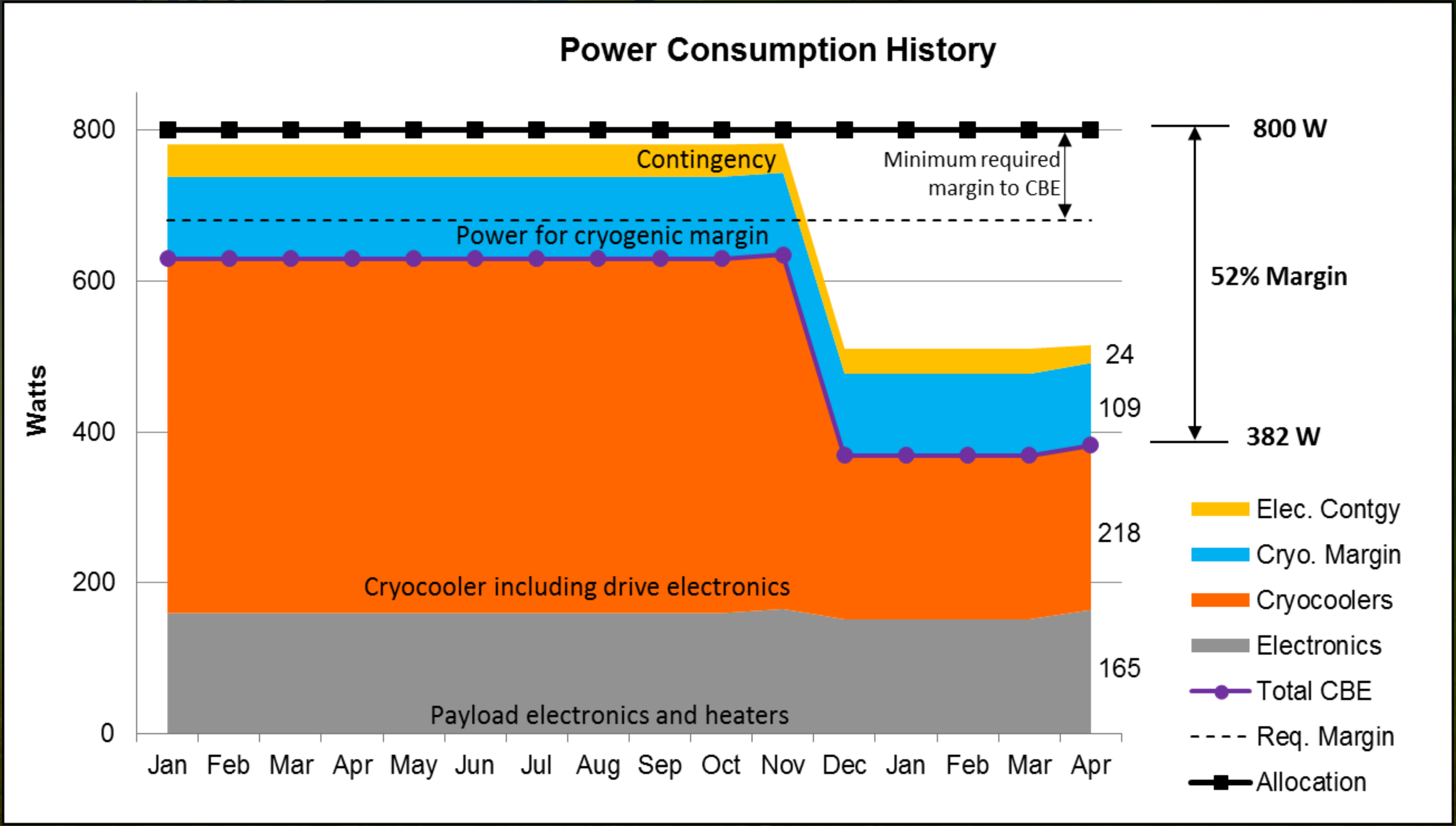
Mass

- Updated as-build mass of MSU, CCM, PCE and Close-out Panel.

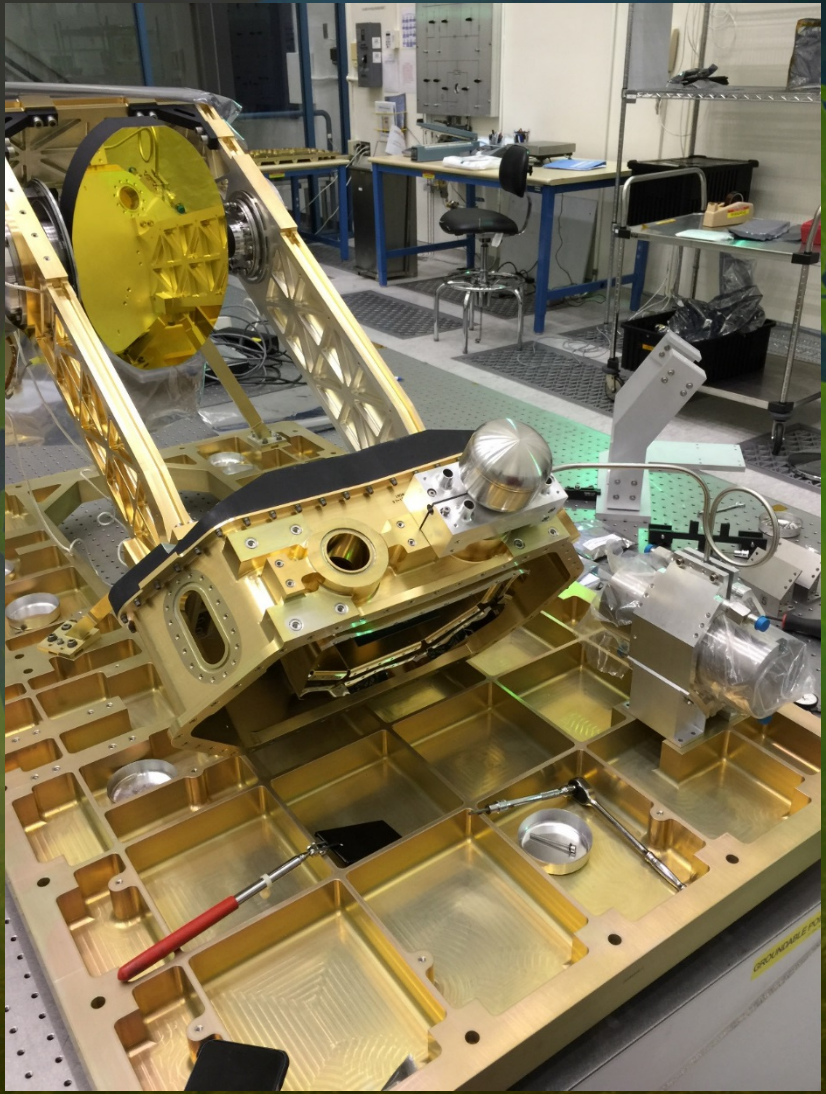


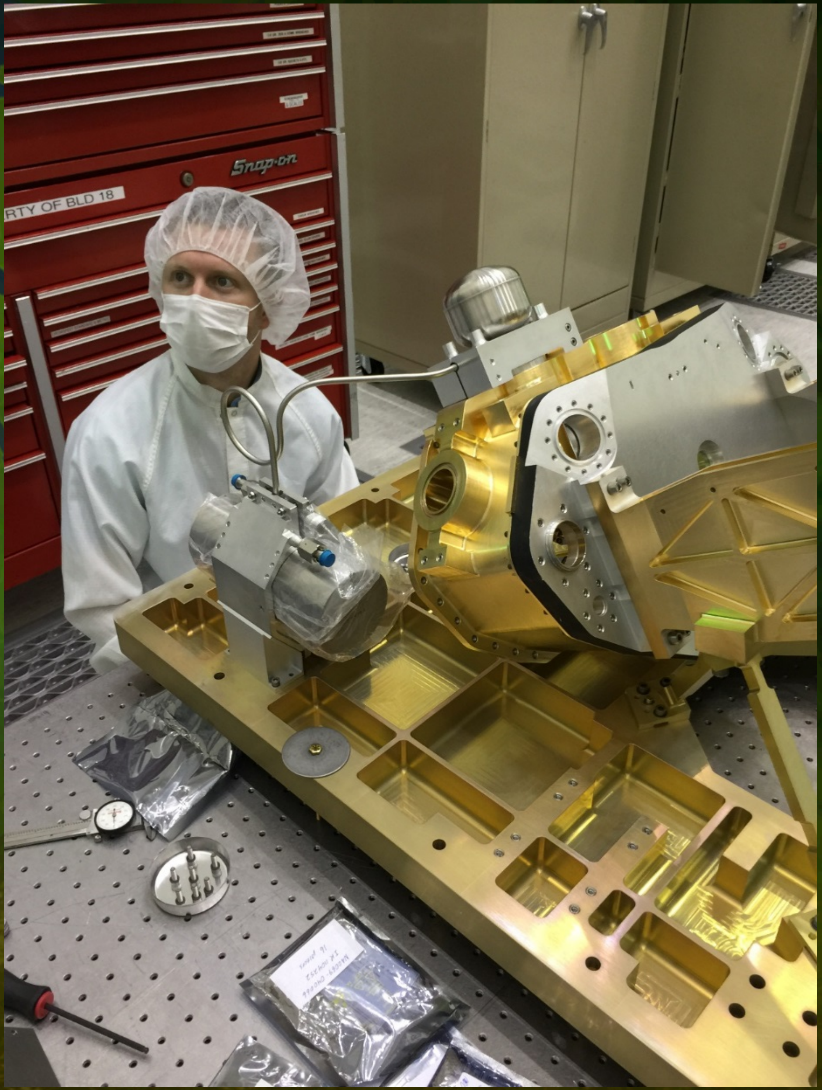
Power

- FPIE power updated with measured power.



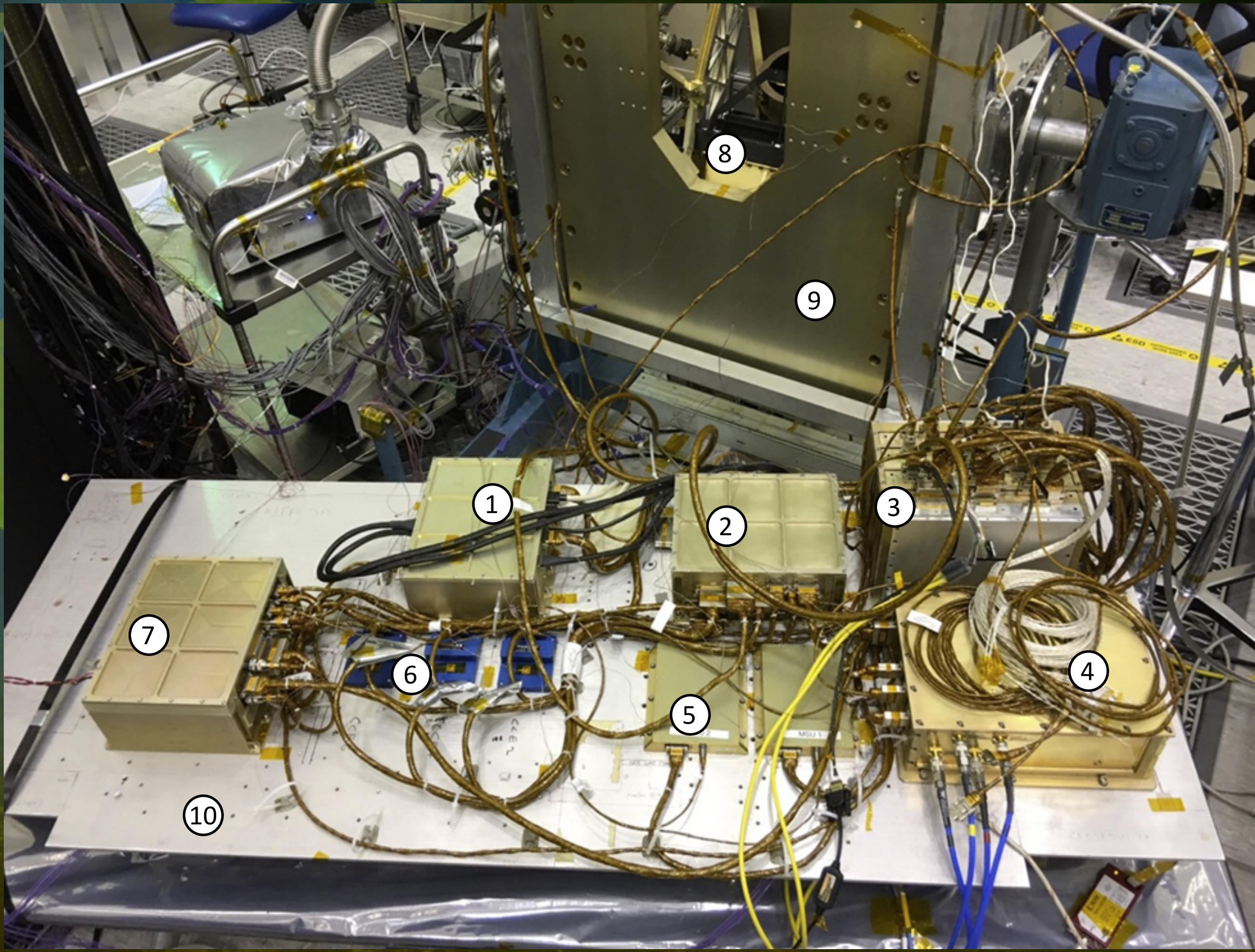
EM Cryocooler Installation





ECOSTRESS Electronics Development

1. Focal Plane Interface assembly
2. Cryocooler multiplexer assembly
3. Central electronics unit
4. WiFi electronics box assembly
5. Mass storage unit
6. Cryocooler electronics
7. Power condition
8. Radiometer Instrument
9. Nadir Panel
10. GSE Hot Plate



ECOSTRESS electronics ambient thermal cycling test configuration

ECOSTRESS

- Some facts and figures
  - Focused on water use and availability
  - Selected in EVI-2
  - Class D mission on ISS
  - Uses PHyTIR developed under ESTO IIP
  - Deliver in early 2017
  - Launch in mid 2018
  - Nominal mission lifetime 1 year

L1 Science Requirements and Margins

Parameter	Science Requirement (from PLRA)	Current Best Estimate @ 400 km
Ground Sample Distance (m) Crosstrack x Downtrack at nadir	≤ 100 x ≤100	68.5 x 38.5
Swath width (ISS nominal altitude range is 385 to 415 km)	≥ 360	402
Wavelength range (µm)	8-12.5	8-12.5
Number of bands	≥ 3	5 TIR + 1 SWIR
Radiometric accuracy (K @300K)	≤ 1	0.5
Radiometric precision (K @300K)	≤ 0.3	0.15-0.25
Dynamic Range (K)	270-335	200-500
Data collection	CONUS, twelve 1,000 x1,000km key climate biomes and twenty-five FLUXNET sites. On average 1 hour of science data per day.	1.5 hours per day of science data

ECOSTRESS Science Data Products

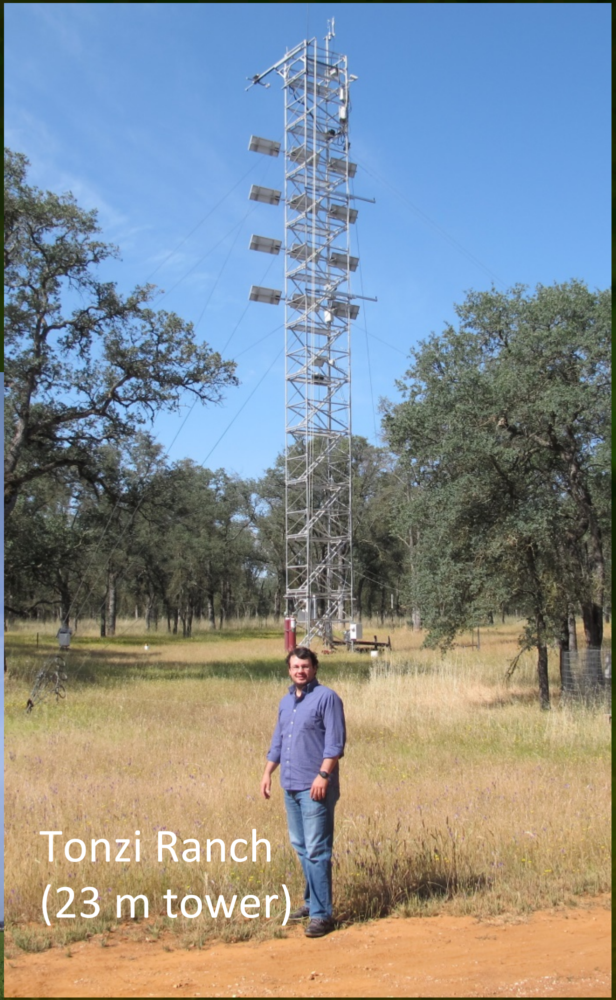
Data Product	Description	Initial Availability to NASA DAAC	Median Latency in Product Availability to NASA DAAC after Initial Delivery	NASA DAAC Location
Level 0	Raw collected telemetry	6 months after IOC	12 weeks	LPDAAC
Level 1	Calibrated Geolocated Radiances	6 months after IOC	12 weeks	LPDAAC
Level 2	Surface temperature and emissivity	6 months after Level 1 data products are available	12 weeks	LPDAAC
Level 3	Evapotranspiration	2 months after Level 2 data products are available	12 weeks	LPDAAC
Level 4	Water use efficiency and evaporative stress index	2 months after Level 3 data products are available	12 weeks	LPDAAC

Calibration and Validation

- On-board blackbodies
- Vicarious calibration sites
- Validation sites (FLUXNET)

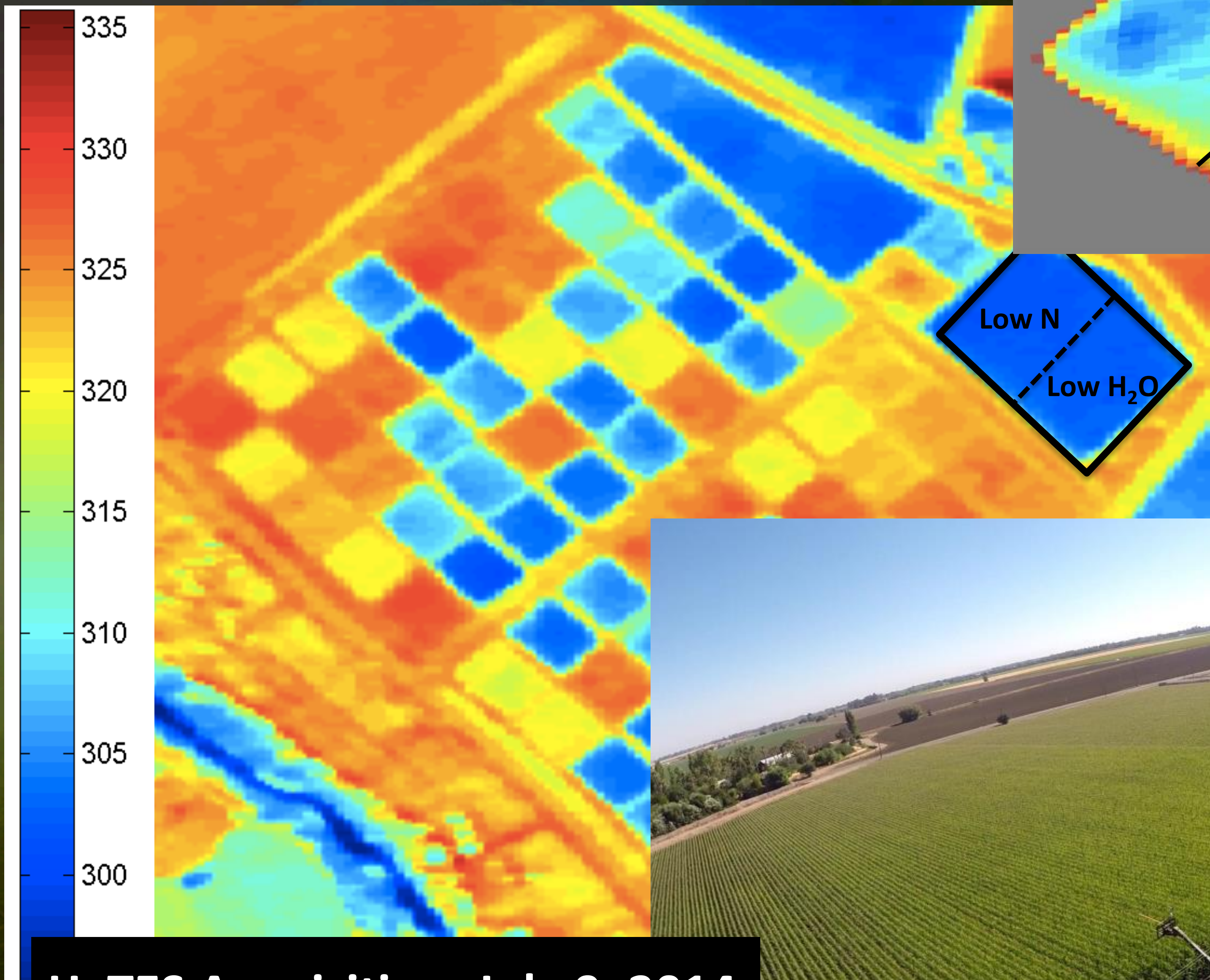
Lake Tahoe

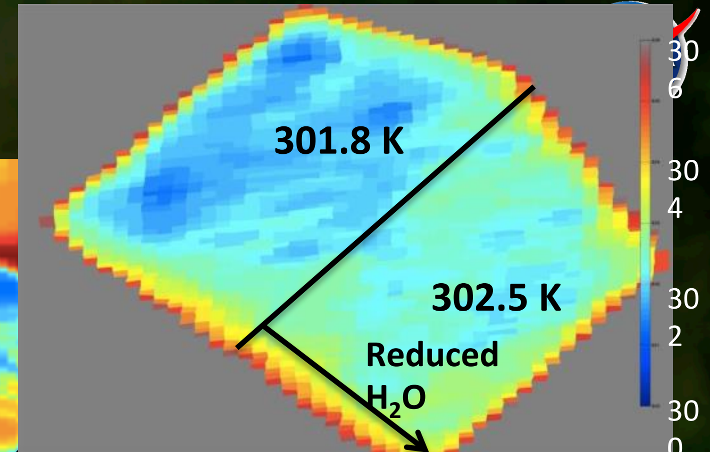
Russell Ranch



Tonzi Ranch (23 m tower)

Using JPL Airborne Instruments for Precursor Studies:





<u>HyTES Acquisition: July 9, 2014</u>

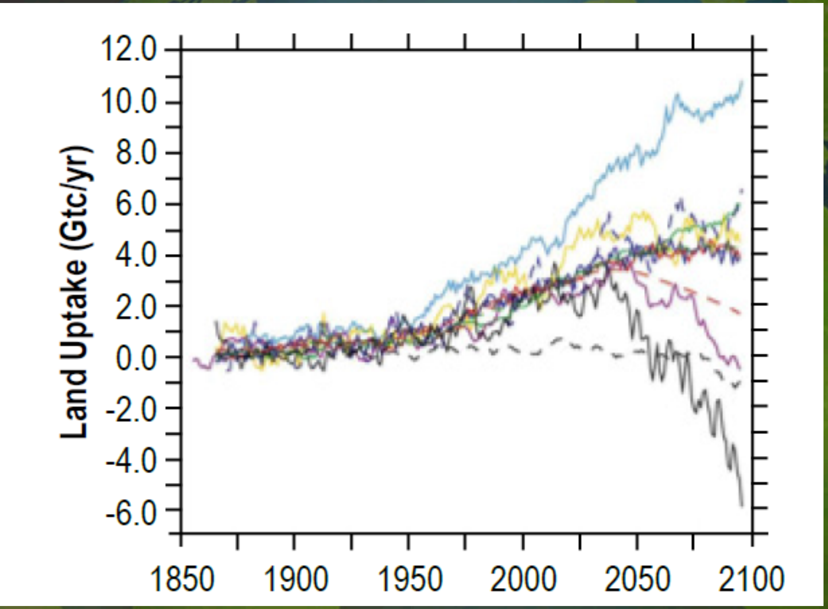
Summary

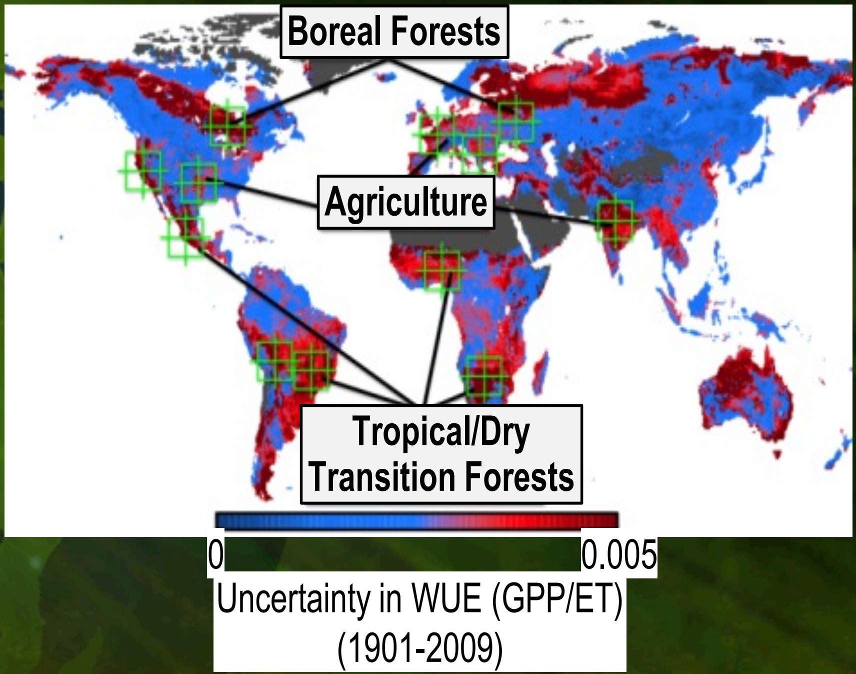
- ECOSTRESS is possible because of the development of the PHyTIR instrument for HyspIRI-TIR supported by ESTO
- ECOSTRESS will address a subset of the science associated with HyspIRI
- The ECOSTRESS mission will help answer three key science questions:
  - How is the terrestrial biosphere responding to changes in water availability?
  - How do changes in diurnal vegetation water stress impact the global carbon cycle?
  - Can agricultural vulnerability be reduced through advanced monitoring of agricultural water consumptive use and improved drought estimation?
- ECOSTRESS has a clearly defined set of data products and mature algorithms
- Opportunity for combined HyspIRI-like datasets using the European EnMAP/PRISM and ECOSTRESS with GEDI for structure

ECOSTRESS will launch in 2018 and provide highest spatial resolution thermal infrared data ever from the International Space Station. HyspIRI is planned for the 2023+ timeframe unless the Decadal Survey increases the priority !!

BACKUP

Q1. How is the terrestrial biosphere responding to changes in water availability?

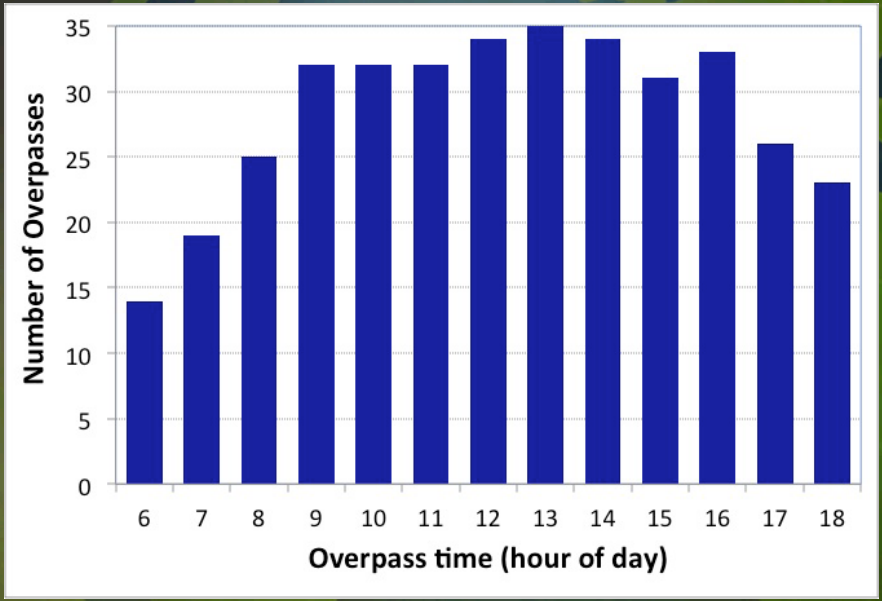




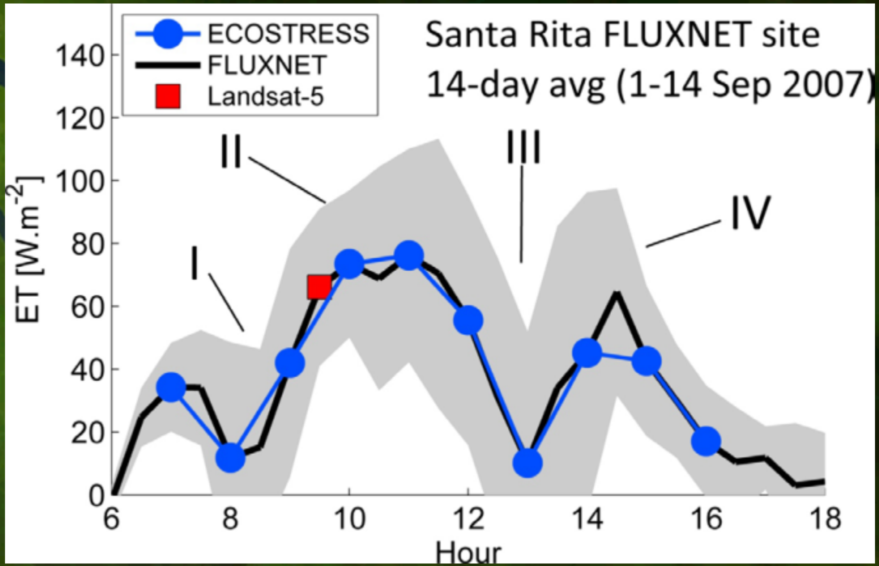
Uncertainty in our knowledge of carbon response is directly dependent on water response uncertainty and how plants use water under drying conditions.

Red areas ("hotspots") are where global models disagree on water use efficiency (WUE) based biome changes with climate change. ECOSTRESS will reduce this uncertainty with measurements for WUE (GPP/ET).

Q2. How do changes in diurnal vegetation water stress impact the global carbon cycle?



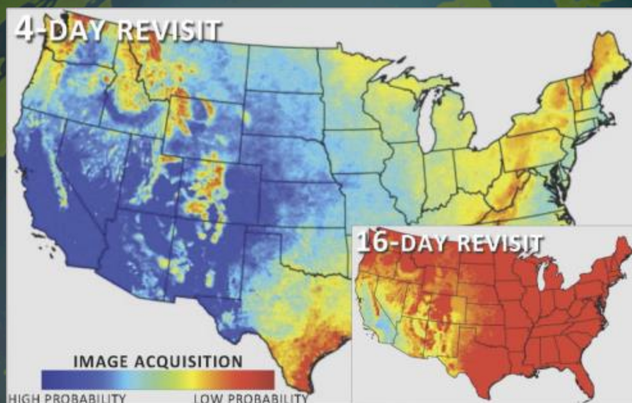
ECOSTRESS acquires numerous samples throughout the day over 1 year (at 50o latitude shown, for example).



ECOSTRESS's diurnal sampling measures the shape of the daily ET cycle. The afternoon decline in ET is related to water stress (clear day).

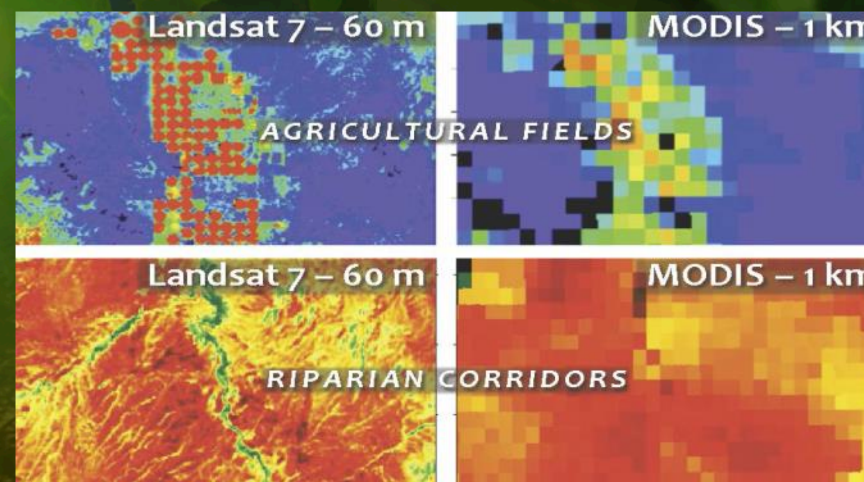
I: Xylem refilling after initial water release.
II: ET at maximum/potential rate in the morning.
III: Stomata shut down water flux in the afternoon.
IV: ET resumes at maximum/potential in early evening when demand is reduced

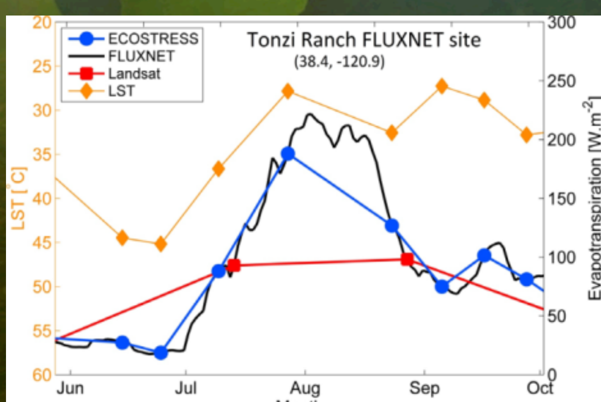
Q3. Can agricultural vulnerability be reduced through advanced monitoring of agricultural water consumptive use and improved drought estimation?



Probability of producing valid ET estimates when satellite revisit time is 16 days (lower-right inset) vs. 4 days

ECOSTRESS's spatial resolution will distinguish fine-scale landscape heterogeneity such as agricultural systems (top) and riparian corridors (bottom) similar to Landsat (left), whereas MODIS (right) does not.



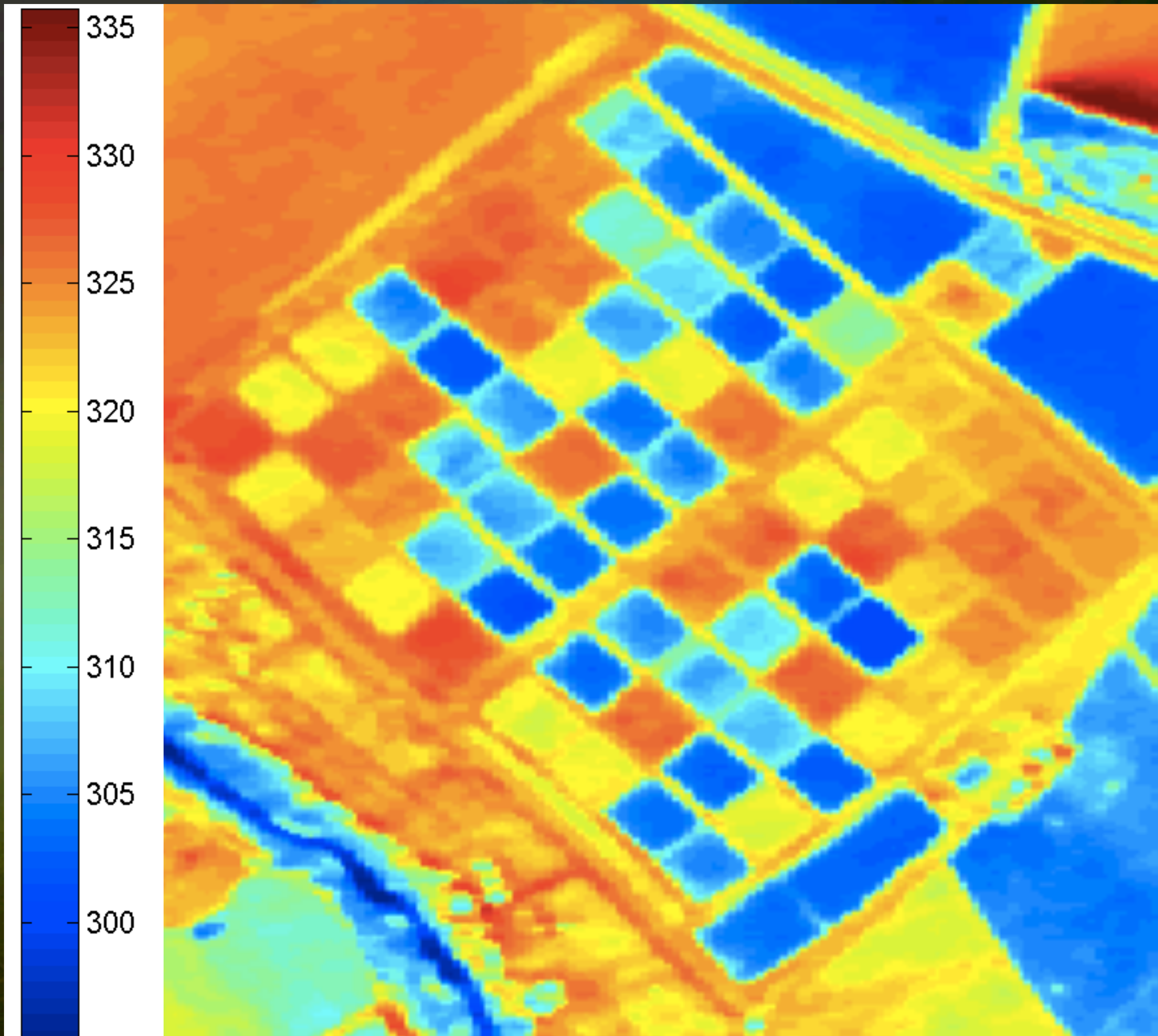


ECOSTRESS's temporal resolution provides a *9-fold* decrease in ET error relative to Landsat.

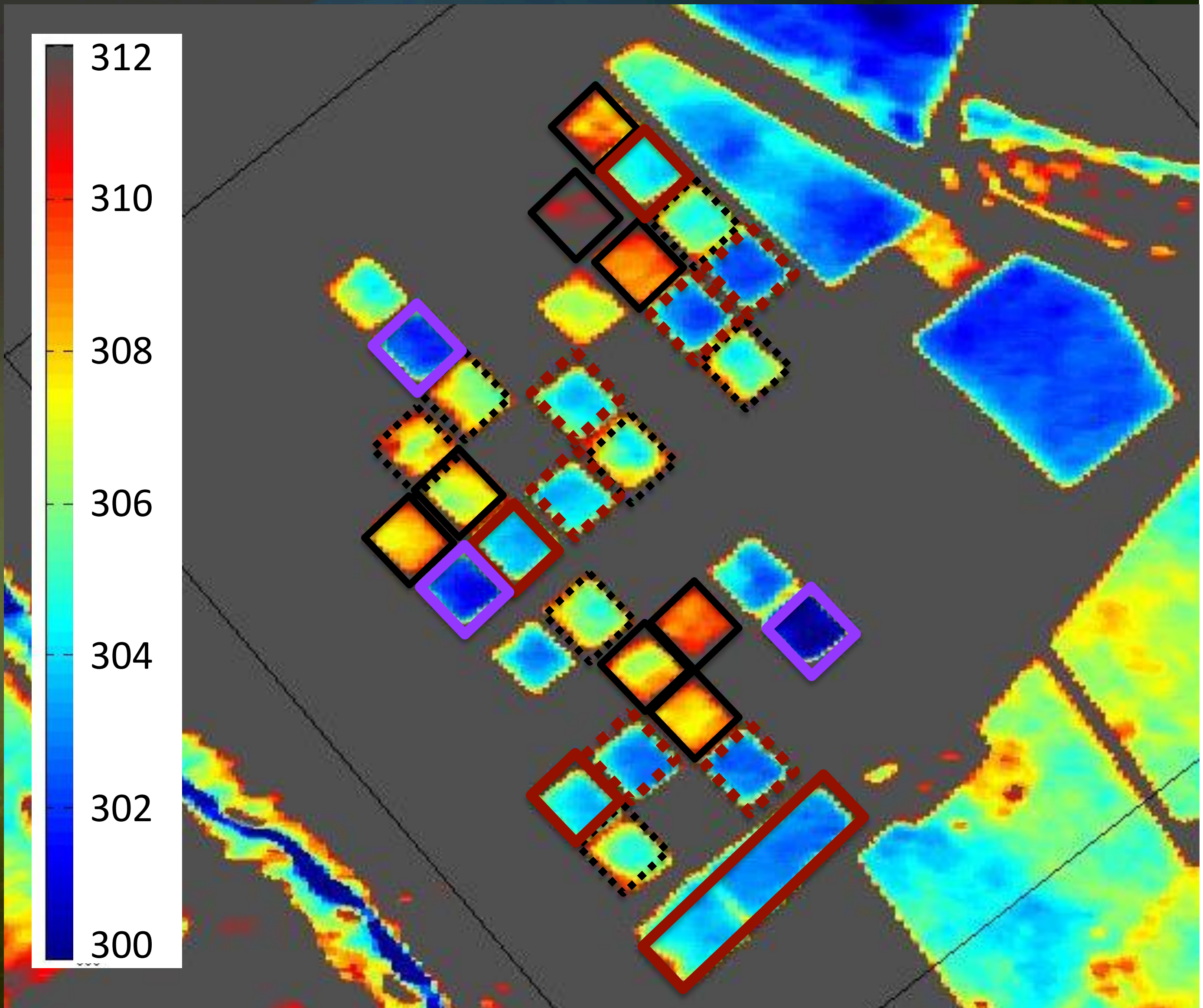
HyTES: Hyperspectral Thermal Emission Spectrometer

JPL Airborne Capability

Image Acquisition: 9 JUL 2014



HyTES Acquisition: July 9, 2014



Irrigated July 7-8:

Organic Tomato

→ **Mean LST = 309 K**

Conventional Tomato

→ **Mean LST = 306 K**

Irrigated July 2-3:

Organic Corn

→ **Mean LST = 304 K**

Conventional Corn

→ **Mean LST = 303 K**

Alfalfa

→ **Mean LST = 301.5 K**